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THEORETICAL AND EXPERIMENTAL STUDIES IN ASTROPHYSICS

Prepared by:

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CONTENTS

1: Introduction

This report summarises research activities in Laboratory Astrophysics and Aeronomy, carried out by the Molecular Excitation Group, University of Western Ontario, between February 1st 1965 and July 31st 1965.

Of particular note is the fact that Dr. R. W. Nicholls has left the University of Western Ontario on June 30 1965, to take up the Chairmanship of the Department of Physics, and the Directorship of the Centre for Research in Experimental Space Sciences, at York University in Toronto. Several other personnel changes have also taken place during the report period, as are indicated below.

Although the number of people engaged in research supported by this grant has decreased, the National Aeronautics and Space Administration has approved transfer of the remaining funds to Dr. H. I. S. Ferguson from Dr. Nicholls, effective July 1 1965, and to extend the period over which these funds may be spent to January 31 1967 from January 31 1966. This transfer, and extension, is gratefully acknowledged.

The entire Physics and Chemistry Building at the University of Western Ontario is undergoing a complete renovation, which began in April 1965, as the Physics Department is taking over the entire building. This has been taken as an opportunity for a much needed regrouping of research facilities, but in spite of serious disruptions to all (these were compounded by a building trades strike of several weeks), it has been possible to maintain satisfactory progress with research. As indicated below, many of the graduate students are writing theses, while most of the others have the end of their experimental programmes in sight.

2: Overall Research Programme

This is unchanged in scope from the last report but is listed again for completeness. Many aspects of the programme will be discontinued here when the graduate students concerned are finished, as much of the equipment will go to York University.

Experimental

Intensity measurements on molecular spectra

Atlas of molecular spectra

Shock tube spectroscopy

Plasma jet studies

Ion beam spectroscopy

X-radiolysis of gases

Impact flash spectroscopy

Laser excitation of powdered solids

Theoretical

Studies of molecular potentials and wave functions

Studies of derived quantities of vibrational wave functions

Vibration-rotation studies

Atomic (e+H) collisions

3: Personnel

The following personnel have contributed to the research programme (those indicated by ** now at York University).

Faculty:

**Dr. R.W. Nicholls, Senior Professor of Physics (Director to June 30 1965)

Dr. H.I.S. Ferguson, Associate Professor of Physics (Assoc. Director, Experimental to June 30 1965)

Dr. P.A. Fraser, Professor of Physics (Assoc. Director, Theoretical to June 30 1965)

**Dr. G.R. Hébert, Assistant Professor of Physics

Dr. R.C. Murty, Assistant Professor of Physics

Mr. W.R. Jarmain, Lecturer in Physics (Assistant Professor of Physics as of July 1 1965)

Visiting Assistant Professor

**Dr. D.C. Tyte (previously National Research Council of Canada Post Doctoral Fellow)

Graduate Students (Supported by scholarship as indicated)

Mr. V. Degen

Mr. G.W.F. Drake (NRC Scholarship)

Mr. J.P. Fallona

Mr. M. Kraidy

Miss I.S. Lee

Mr. R.P. Lowe (DRB on leave)

Mr. J.E. Mentall

Mr. A. MacGregor (NRC Scholarship)

Mr. D.J. McEwen (DRB on leave)

Mr. F. Morgan (NRC Scholarship)

Mr. J.A. Myer (ORF Scholarship)

Graduate Technical Assistants

**Mr. R.A. Koehler

Mr. W. Doan (Summer 1965)

Mrs. M. Murty

Mrs. S. Innanen

Technician

**Mr. J. Radema

Secretary

Mrs. D. Sass (terminated June 30 1965)

4: Experimental Studies

4.1 Intensity Measurements on Molecular Spectra

Mr. McEwen completed his intensity measurements on the Lyman-Birge-Hopfield system of N_2 (an important contributor to the vacuum u.v. spectrum of the aurora), after developing calibration techniques for the vacuum u.v. region (9). (Bracketed numbers refer to references in Section 6 of this report). He was awarded the Ph.D. degree in June 1965 and has returned to DRB.

Dr. Tyte has studied the influence of environmental effects on the intensity distribution of the First Negative System of N_2^+ (2).

Dr. Hébert has continued intensity measurements on the CO Fourth Positive System. This system is probably a contributor to the aurora and/or airglow of Venus. It has also been shown to be an important contributor to the Solar spectrum.

Mr. Degen has almost completed intensity measurements on the O_2 Herzberg system, which is an important contributor to the spectrum of the airglow.

Mr. Drake has completed an experimental and theoretical study of the intensity distribution in the BeO Blue-Green System. He is writing a M.Sc. thesis.

Mr. Fallona continues to work on a number of CO band systems.

4.2 Shock tube Spectroscopy

Dr. Tyte continued studies of the Blue-Green (A-X), Violet (B-X), and Infrared (B-A) Systems of AlO. He has been working on the correct identification of the fragmentary u.v. systems (2500 A) using isotopically substituted $Al_2O(Al_2O_3{}^{18})$.

Mr. Myer has almost completed his studies of shock wave - powder particle interactions, and is starting on a M.Sc. thesis.

Mr. MacGregor has almost completed oscillator strength measurements of shock excited MgH bands, and has made a start on a Ph.D. thesis.

4.3 Plasma Studies

Mr. Morgan has completed his spectroscopic and probe studies on the argon plasma jet. He was awarded the Ph.D. degree in June 1965 (10), and is now with the Culham Laboratories in the United Kingdom.

4.4 Ion Beam Spectroscopy

Mr. Lowe has completed his spectroscopic studies of 2–10 KeV alkali ion beams into a variety of gases, and is writing a Ph.D. thesis. He has published some of this work (1).

Dr. Ferguson has been closely associated with the above work. He is also engaged in further developing a proton accelerator (40–100 KeV). This has been completely dismantled for moving to a new location. Considerable reconstruction is necessary, and this is just beginning.

4.5 Impact Flash Spectroscopy

Mr. Koehler completed this work just prior to the report period, and was awarded the M.Sc. degree in June 1965 (12).

4.6 Laser Excitation of Powdered Solids

Mr. Mentall has almost completed his quantitative spectroscopic studies, and is starting on a Ph.D. thesis. He has published some aspects of his work (17).

5: Theoretical Studies

5.1 Atomic Collisions

Mr. Doughty completed his theoretical studies of the bound-free and free-free transitions of the Negative Hydrogen Ion, and was awarded the Ph.D. degree

in June 1965 (11). He is now at University College in London.

Dr. McEachran, Dr. Fraser, Mr. Wallace and Mr. Tull have developed a version of a variation-iteration method of solution of atomic collisions problems (16).

Mr. Kraidy and Dr. Fraser are extending iterative methods of solution of equations of atomic collision theory.

Drs. McEachran and Fraser have completed a theoretical study of positron-hydrogen atom collisions (8).

Mr. Kraidy and Dr. Fraser are also studying positron-helium collisions, and Dr. Fraser is studying positronium-helium collisions.

5.2 Franck-Condon Factors

Dr. Nicholls has continued his computation of Franck-Condon factor arrays to high vibrational quantum numbers. Arrays for a number of band systems have been published or are in press (3, 4, 5, 6, 7). A successful study of methods of interpolation between arrays of Franck-Condon factors has been made (15).

Mr. Jarmain has continued his computations of Franck-Condon factors and densities appropriate to realistic potentials for the $v'' = 0, 1$ progressions and photo-dissociation continuum of the Herzberg system of O_2.

6: Publications

6.1 Published Papers (appeared during report period)

(1) The Distribution of Rotational Energy in N_2^+ excited by 3 KeV Li^+ Ions
Proceedings of the Physical Society 85, 813, 1965
R.P. Lowe and H.I.S. Ferguson

(2) The Effect of Environmental Conditions on Band Strengths
Journal of Quantitative Spectroscopy and Radiative Transfer 5, 545, 1965
D.C. Tyte

(3) Franck-Condon Factors to High Vibrational Quantum Numbers V: O_2
Journal of Research of the National Bureau of Standards 69A, 369, 1965
R.W. Nicholls

(4) Franck-Condon Factors to High Vibrational Quantum Numbers VI: C_2
Journal of Research of the National Bureau of Standards 69A, 397, 1965
R.W. Nicholls

(5) Franck-Condon Factors for the Gaydon-Green System of N2
Journal of Chemical Physics 42, 804, 1965
R.W. Nicholls

(6) Franck-Condon Factors for the H_2 Lyman System
Astrophysical Journal 141, 819, 1965
R.W. Nicholls

(7) Franck-Condon Factors for the O_2^+ First and Second Negative Systems
Canadian Journal of Physics 43, 1390, 1965
R.W. Nicholls

(8) The Elastic Scattering of Low Energy Positrons by Atomic Hydrogen
Proceedings of the Physical Society 86, 369, 1965
R.P. McEachran and P.A. Fraser

6.2 Theses

(9) Intensity Measurements on the Lyman-Birge-Hopfield System of N_2
Ph.D. thesis, 1965, University of Western Ontario
D.J. McEwen

(10) Temperature Measurements in a Weakly Ionised Plasma Jet
Ph.D. thesis, 1965, University of Western Ontario
F.J. Morgan

(11) The Negative Hydrogen Ion Absorption Coefficients
Ph.D. thesis, 1965, University of Western Ontario
N.A. Doughty

(12) Spectroscopic Study of the Impact Flash
M.Sc. thesis, 1965, University of Western Ontario
R.A. Koehler

6.3 Publications in Press

(13) The Bound-Free Absorption Coefficient of the Negative Hydrogen Ion
Monthly Notices of the Royal Astronomical Society
N.A. Doughty, P.A. Fraser and R.P. McEachran

(14) The Free-Free Absorption Coefficient of the Negative Hydrogen Ion
Monthly Notices of the Royal Astronomical Society
N.A. Doughty and P.A. Fraser

(15) Interpolation of Franck-Condon Factor Arrays for Molecular Band Systems
Journal of Quantitative Spectroscopy and Radiative Transfer
R.W. Nicholls

(16) The Application of an Iteration-Variation Method to Atomic Scattering Problems
Proceedings of the Physical Society
R.P. McEachran, P.A. Fraser, J.B.G. Wallace, C.E. Tull

(17) Absolute Band Strengths for the C_2 Swan System
Proceedings of the Physical Society
J.E. Mentall and R.W. Nicholls

6.4 Orally Presented Papers

Shock Tube Spectroscopy of Shock Excited Powdered Solids
5th Shock Tube Symposium (May 1965)
R.W. Nicholls and D.C. Tyte

Spectroscopic Temperature Measurements on Laser Flames from Solids
American Physical Society (May 1965)
J.E. Mentall and R.W. Nicholls